TREATMENT FOR CARDIOVASCULAR AND RELATED DISEASES

CROSS-REFERENCE TO RELATED APPLICATION

This application is a U.S. National Phase Application filed under 35 U.S.C. § 371 based on International Application No. PCT/AU95/00875, having an International Filing Date of Dec. 22, 1995.

TECHNICAL FIELD

THIS INVENTION relates to plasma or serum delipidation in animals (which term shall indicate humans), to a treatment for cardiovascular disease and to removal of excess fat from the animals. In particular, it is directed to the removal of cholesterol, triglycerides and other lipids, and fat soluble toxins—for example, insecticides—from the blood plasma or serum of such animals.

BACKGROUND ART

Cardiovascular diseases are responsible for a significant number of deaths in most industrialised countries.

One such disease is atherosclerosis which is characterised by local fatty thickening in the inner aspects of large vessels supplying blood to the heart, brain and other vital organs. These lesions obstruct the lumen of the vessel and result in ischaemia of the tissue supplied by the vessel. Prolonged or sudden ischaemia may result in a clinical heart attack or stroke from which the patient may or may not recover.

The relationship between dietary lipid, serum cholesterol and atherosclerosis has long been recognised. In many epidemiological studies it has been shown that a single measurement of serum cholesterol has proved to be a significant predictor of the occurrence of coronary heart disease.

Thus diet is the basic element of all therapy for hyperlipidaemia (excessive amount of fat in plasma). However, the use of diet as a primary mode of therapy requires a major effort on the part of physicians, nutritionists, dietitians and other health professionals.

If dietary modification is unsuccessful, drug therapy is an alternative. Several drugs, used singly or in combination, are available. However, there is no direct evidence that any cholesterol-lowering drug can be safely administered over an extended period.

A combination of both drug and diet may be required to reduce the concentration of plasma lipids. Hypolipidaemic drugs are therefore used as a supplement to dietary control.

Many drugs are effective in reducing blood lipids, but none work in all types of hyperlipidaemia and they all have undesirable side effects. There is no conclusive evidence that hypolipidaemic drugs can cause regression of atherosclerosis. Thus, despite progress in achieving the lowering of plasma cholesterol to prevent heart disease by diet, drug therapies, surgical revascularization procedures and angioplasty, atherosclerosis remains the major cause of death in Western Countries.

In view of the above, new approaches have been sought to reduce the amount of lipid in the plasma of homozygotes and that of heterozygotes for whom oral drugs are not effective.

Plasmapheresis (plasma exchange) therapy has been developed and involves replacement of the patient's plasma with donor plasma or more usually a plasma protein fraction.

This treatment can result in complications due to the possible introduction of foreign proteins and transmission of infectious diseases. Further, plasma exchange removes all the plasma proteins as well as very low density lipoprotein (VLDL), low density lipoprotein (LDL), and high density lipoprotein (HDL).

It is known that HDL is inversely correlated with the severity of coronary arterial lesions as well as with the likelihood that these will progress. Therefore, removal of HDL is not advantageous.

Known aphaeresis techniques also exist which can remove LDL from plasma. These techniques include absorption of LDL in heparinagarose beads (affinity chromatography) or the use of immobilised LDL-antibodies. Other methods presently available for the removal of LDL involve cascade filtration absorption to immobilised dextran sulphate and LDL precipitation at low pH in the presence of heparin. Each method specifically removes LDL but not HDL.

LDL aphaeresis has, however, disadvantages. Significant amounts of other plasma proteins are removed during aphaeresis and to obtain a sustained reduction in LDL-cholesterol, LDL aphaeresis must be performed frequently (up to once weekly). Furthermore, LDL removal may be counter productive as. low blood LDL levels may result in increased cellular cholesterol synthesis.

To satisfy the need for a method of achieving a reduction in plasma cholesterol in homozygous familial hypercholesterolemia, heterozygous familial hypercholesterolemia and patients with acquired hyperlipidaemia other than by diet, drug therapy, LDL aphaeresis, or a combination of these, an extra corporeal lipid elimination process, termed "cholesterol aphaeresis", has been developed. In cholesterol aphaeresis, blood is withdrawn from a subject, plasma separated from the blood and mixed with a solvent mixture which extracts lipid from the plasma, after which the delipidated plasma is recombined with the blood cells and returned to the subject.

In more detail, cholesterol aphaeresis results in the removal of fats from plasma or serum. However, unlike LDL aphaeresis, the proteins that transport the fat (apolipoproteins) remain soluble in the treated plasma or serum. Thus the apolipoproteins of VLDL, LDL and HDL are present in the treated plasma or serum. These apolipoproteins, in particular apolipoproteins AI from the defatted HDL in the plasma or serum, are responsible for the mobilisation of excessive amounts of deposited fats such as cholesterol in arteries, plaques, or excessive amounts of triglycerides, adipose tissue, or fat soluble toxins that are present in adipose tissue. These excessive amount of fats or toxins are transferred to the plasma or serum, bound to the newly assembled lipoproteins. Thus by applying another cholesterol aphaeresis procedure, these unwanted fats or toxins are successively removed from the plasma and thus the body.

The main advantage of this procedure is that LDL and HDL are thus not removed from the plasma but only cholesterol, some phospholipids and considerable triglycerides. U.S. Pat. No. 4,895,558 describes such a system.

While cholesterol aphaeresis has overcome the shortcomings of dietary and/or drug treatments and other aphaeretic techniques, existing apparatus for cholesterol aphaeresis does not provide a sufficiently rapid and safe process. For use in a clinical setting, apparatus is required which effects delipidation more efficiently. Furthermore, flow rates of the order of 70 ml/min are required for cholesterol aphaeresis of a human subject.

Thus the cholesterol aphaeresis described in the aforementioned U.S. Pat. No. 4,895,558 was improved by incorporating into the system a spinner to disperse the incoming plasma laterally into the extracting solvent in the form of fine droplets to improve separation efficiency. This improved system is described in International Patent Application No. PCT/AU94/00415.

Unfortunately, practice has established that the cholesterol aphaeresis systems described above still suffer from a number of disadvantages.

The first disadvantage is the explosive nature of the solvents used to delipidate this plasma. These solvents are, by the very nature of the continuous systems, in close proximity to the patient and medical staff. This hazard is clearly present for the duration of the delipidation process which usually runs for several hours.

The second disadvantage is that, in the prior continuous systems, a reliable procedure is not available to remove totally all of the solvents used in the delipidation before the treated plasma is returned to the patient.

In particular, the use of the preferred solvent 1-butanol in the delipidation is of concern as it can now be established that that solvent can be present as 1% to 5% of the treated plasma that is returned to the patient. This is because continuous systems can only include a single wash to remove solvents such as 1-butanol and a single wash is now found to be insufficient. It is not possible to provide sequential multi-washes in a continuous system because the patient would have to supply an unacceptable volume of blood to maintain each stage of the system overall and the patient would also be subjected to an increased hazard factor from the prolonged exposure to the solvents.

The long term toxicity of 1-butanol is not known, especially when directly present in the blood stream—it may cross the blood brain barrier. Certainly, external contact with this solvent is known to cause irritation of mucous membranes, contact dermatitis, headaches, dizziness and drowsiness.

A third disadvantage is that the continuous systems described above are not suitable for the delipidation of serum. If serum can be delipidated, there would be the advantage of favourably altering the blood rheology in that the viscosity will decrease following delipidation resulting in better haemodynamics for the originally impaired blood circulation.

Yet a fourth disadvantage is that delipidation in a continuous system is undertaken over several hours. Apart from the prolonged exposure to the hazardous solvents as discussed above, the equipment and staff are committed to a single patient. As the removal of plasma or other blood fractions and their subsequent return to the patient as individual steps each only take a few minutes, it would be advantageous if the relatively lengthy delipidation step could be undertaken off site, thus freeing the patient, medical staff and equipment for other matters.

Finally, in a continuous system, clearly it is only the patient's own blood fraction that can be returned to that patient. However, for example, if the patient's plasma or serum could be removed and treated remote from the patient, then either autologous or non-autologous plasma or serum could be returned to the patient at a later date.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome, or at least ameliorate, the above-mentioned disadvantages in the

provision of a method for delipidating not only plasma but also serum and other blood fractions which substantially reduces the exposure of the patient to the potentially hazardous solvents used, which also can effectively remove all traces of solvent(s) used in that delipidation, and which significantly reduces the contact time between the patient and the actual delipidation process.

It is a further object to provide a method whereby advantageous changes to the blood rheology of the originally impaired blood circulation of the patient can be achieved.

It is yet another object to provide a method whereby a patient's Plasma or serum can be treated remote from that patient, thus allowing either autologous or non-autologous plasma or serum to be returned to the patient at a later date.

In one aspect of the present invention, there is provided a method for the removal of cholesterol, triglycerides and other lipids from animal plasma, serum or other suitable blood fractions, as a discontinuous flow system, said method comprising withdrawing blood from a subject, separating the required fraction from the blood and mixing with a solvent mixture which extracts the said lipids from the fraction, after which the delipidated fraction is recombined with the blood cells and returned to the subject, characterised in that the solvent extraction step is carried out separately and remote from the subject.

Preferably, as part of the solvent extraction step, beads are used when mixing the blood fractions with the solvent. More preferably, the beads have a density substantially mid-way between the density of the fraction and the density of the solvent mixture. This ensures efficient mixing with a large surface area, increasing the efficiency of the extraction and also serving as a good separator of the plasma from the solvent when centrifugation is used to isolate the phases after extraction.

Preferably, to obtain a density substantially mid-way between the density of the fraction and the density of the solvent mixture, the beads contain entrapped air.

More preferably, as the density of plasma is approximately 1.006 g/ml and the solvents used generally have a density of approximately 0.8 g/ml, the density of the beads will be around 0.9 g/ml.

The beads may be manufactured from any acceptable material such as glass or plastic.

Once the resultant delipidated fraction-containing phase has been isolated, all traces of the extraction solvent must be removed before the fraction is recombined with the blood cells and/or returned to the subject.

One way of removing this solvent is to wash with another solvent, preferably diethyl ether, to remove substantially all of the original solvent used in the extraction step.

More preferably, four (4) washes are undertaken.

However, as another aspect of the present invention, efficient removal of the extraction solvent can be achieved by mixing the delipidated fraction with an absorbent specific for the solvent that is being removed.

In particular, the absorbent is contained in the pores of sintered spheres.

More preferably, the sintered spheres are approximately 2 to 5 mm in diameter with the pores of the spheres being less than 50 Å in diameter. Most preferably, the spheres are manufactured from glass.

Preferably, the absorbents used in the sintered spheres are the macroporous polymeric beads for absorbing organic molecules from aqueous solutions marketed by Bio-Rad Laboratories under the trade name Bio-Beads SM.

If the solvent used to delipidate the fraction is 1-butanol, then the absorbent is preferably Bio-Beads SM-2.

Preferably, the absorbent is held in a chamber which is adapted to allow the delipidated fraction to pass through or over the absorbent at least twice if a single pass is insufficient to remove all of the solvent.

Preferably, as part of isolating the delipidated fraction-containing phase, that phase is subsequently washed with another solvent, preferably diethyl ether, to remove a substantial amount of the original solvent before the treatment with the absorbent.

More preferably, that phase is washed at least three (3) times.

The plasma may be human plasma or plasma from other living animals. The plasma can be obtained from human or animal blood by known plasma separating techniques which include centrifugal separation, filtration and the like.

Similarly, the serum or other lipid-containing fraction can be derived from human or other living animals by known techniques.

Suitable solvents for the extraction comprise mixtures of hydrocarbons, ethers and alcohols. Preferred solvents are mixtures of lower alcohols with lower ethers. The lower alcohols suitably include those which are not appreciably miscible with the plasma and these can include the butanols (butan-1-ol and butan-2-ol). C_{1-4} ethers are also preferred and these can include the propyl ethers (di-isopropyl ether and propyl ether). Other solvents which may be applicable include amines, esters, hydrocarbons and mixtures providing that the solvent can (1) rapidly and preferably remove cholesterol from the plasma, (2) is substantially immiscible with the plasma, (3) can be removed from the plasma, and (4) does not denature the desired moieties. Preferred solvent compositions are butanol with di-isopropyl ether and these may be in the ratio of 0%–40% of the alcohol to 100%–60% of the ether.

DETAILED DESCRIPTION OF EMBODIMENTS

Materials and Methods

Animals

The roosters used in this study were of White Leghorn Hiline strain and were obtained as one-day old chicks. All roosters from 8 weeks old were transferred into individual cages. Water and feed were supplied unrestricted. At eight weeks of age, 15 control birds were fed a commercial poultry ration for 31 days and another group of 30 birds were injected subcutaneously each day with 5 mg diethylstilboestrol (DES) in sesame oil for a period of 31 days. In addition they were fed on the same commercial diet which was supplemented with 2.6% (w/w) cholesterol for a period of 31 days. Fifteen animals of the DES treated group were then subjected to lipid aphaeresis (LA). Fifteen animals of the DES treated group had sham treatments. Once the LA or sham treatments commenced, all animals were fed the standard poultry ration, except during the actual treatment itself when animals were kept off their feed for three hours following reinfusion of their autologous blood. Animals were sacrificed two days following the 4th treatment, LA or sham.

Lipid Aphaeresis Procedure

Approximately 25% of the calculated blood volume was collected from a brachial vein of the animal with a 21 gauge needle and syringe. The total blood volume was estimated at 8 percent of the body weight. The blood was collected in heparinized tubes and immediately centrifuged at 900 g for 5 minutes at room temperature. The blood cells were suspended in an amount of saline equivalent to the plasma volume and were reinfused into the animal. The plasma was kept refrigerated for twelve hours and was then delipidated for 20 minutes with a mixture of butanol and di-isopropyl ether (DIPE), 25:75 (v/v), in a ratio of one volume of plasma to two volumes of butanol-DIPE mixture (organic phase). Inert plastic beads with a density of 0.9 g/mL (1 g) were added to the mixture. After extraction, the mixture was centrifuged at 900 g for 2 min to separate the plasma and organic phases. The organic phase (upper layer) was removed, free of plasma phase, by careful aspiration with a pasteur pipette under vacuum. Traces of butanol in the plasma phase were washed out with four volumes of diethyl ether (DEE) for 2 min by end-over-end rotation at 30 rpm. The mixture was then centrifuged at 900 g for 2 min to separate plasma and ether phases. The ether phase was subsequently removed by aspiration with a pasteur pipette. Residual ether was removed by evacuation with a water pump aspirator at 37° C. The plasma was then passed through a 5 mL column containing Bio-Beads SM-2.

This procedure yielded delipidated plasma. The delipidated plasma was re-mixed with the blood cells of a subsequent 25% blood collection which was then reinfused through a brachial vein back into the identical donor animals. The duration of the entire procedure, that is, removal of blood from the animal to reinfusion of treated blood back to the animal was approximately 1 hour. After the fourth lipid aphaeresis treatment, the animals were sacrificed and their livers and aortae were dissected. The LA treatment procedures were repeated 3 times after the first treatment.

Sham Treatment Procedures

This was essentially the same as the LA procedure with the exception of the plasma delipidation with the organic solvents. The blood was collected in heparinized tubes and immediately centrifuged at 900 g for 5 min. The plasma was separated from the blood cells. The blood cells were mixed with saline in the same volume of the collected plasma and reinfused into the animal. The plasma was kept refrigerated for twelve hours and was then remixed with blood cells of a subsequent 25% blood collection after the second and/or subsequent plasma separations. After the fourth lipid aphaeresis treatment, the animals were sacrificed and their livers and aortae were dissected. The sham treatment procedures were repeated 3 times after the first treatment.

Tissue Lipid Preparation

The livers were weighed, minced with a scalpel blade and homogenised in 0.9% sodium chloride solution by 10–12 strokes of a motor driven Teflon-glass homogeniser (1900 rpm). The aorta was weighed and three times its weight of 3 mm glass beads were added in a homogenising bottle containing 0.9% sodium chloride. The contents were then homogenised for one minute. The lipid from the homogenised liver and aorta samples were extracted by the Folch procedure and weighed.